Geological and Geophysical Reconnaissance for the ONR Geoclutter Program

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Grant Number: N00014-00-1-0844
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LONG-TERM GOALS

The common goals of the Geoclutter program are to: (1) understand the acoustic scattering process in shallow water, in order to design physics-based signal processing algorithms to distinguish acoustic returns originating from naturally-occurring features on the world's continental shelves (e.g., iceberg scours, shallow gas accumulations, outcrops of high-amplitude shallow subsurface reflectors, shallowly-buried meandering channels), i.e., “geoclutter”, from man-made targets of similar dimensions (e.g., submarines), and (2) to predict the distribution and properties of geoclutter at a U.S. continental shelf test site, with eventual application to other regions of Navy interest.

OBJECTIVES

To conduct an integrated, interdisciplinary, multi-year initiative, involving both geologists/ geophysicists and acousticians, and involving geologic and ocean acoustics/signal processing field and analysis components, in order: (1) to understand, characterize, and predict lateral and vertical, naturally-occurring heterogeneities (“geoclutter”) both at the seafloor and in the shallow sub-bottom of a U.S. continental shelf test region, and (2) to identify, understand, characterize, and if possible mitigate the geoclutter, specifically the heterogeneities that may produce discrete acoustic returns at low grazing angles, by carrying out precise acoustic reverberation experiments in the same region, so that such false alarms, or detects, of tactical sonar systems can be put in a proper context.

APPROACH

The premise for geoclutter research is that seafloor and shallow sub-seafloor geologic elements contribute to acoustic reverberation in shelfal water depths, in such a way as to affect tactical ASW sonar systems adversely. A comprehensive suite of reverberation measurements on a continental shelf, chosen because that shelf is also well-characterized geologically, should result in improved characterization of linkages between “geoclutter” and the ambient geologic environment. As part of STRATAFORM, a "natural laboratory" to study source-to-sink sediment dispersal and preservation was established on the continental shelf off New Jersey (Figure 1). Seismic interpretation, mapping and limited sampling during STRATAFORM have since been combined with digital compilations of multibeam bathymetry and seafloor backscatter. Continued seafloor characterization during Geoclutter has been motivated by the need to establish acoustic boundary conditions associated with the water/sediment interface. Grab sampling, shallow coring and compressional wave velocity measurements, taken within 1996 STRATAFORM bathymetry and sidescan coverage, were employed to investigate whether or not the backscatter map can be used as a proxy for seafloor velocity. As a result, the New Jersey shelf is the test site for both geoclutter acoustic reconnaissance (Geoclutter Phase I) and detailed geological and geophysical reconnaissance in support of Phase I (Geoclutter Phase II).

The individuals involved at UTIG, other than the Principal Investigators, include another seismic stratigrapher (Gulick), a biostratigrapher (Olson), and a Ph.D. student (Nordfjord). All are part of ongoing Phase II data analysis and interpretation. Collaborations exist with acousticians in Geoclutter Phase I through Dr. N. Makris, MIT. Other Phase II collaborators include Drs. L. Mayer, UNH, C. Alexander, SIO, C. Sommerfield, UDEL, D. Nielson, DOSECC/UUTAH, and S. Schock, FAU.

WORK COMPLETED

Field experiments in support of both phases have now been completed. As a result of Phase I, conducted in April-May 2001, preliminary maps of prospective geoclutter targets have been supplied to UTIG investigators for Areas 1 and 2 (Figure 1). A detailed geophysical characterization of those areas has just been completed for Phase II, in three parts. Part 1 was a cruise by the *Cape Henlopen*, CH01-17 (July 31-August 6, 2001), during which UTIG, UNH, and UDEL investigators collected *in situ* seafloor compressional wave velocity measurements using the ISSAP (*In-situ* Sound Speed and Attenuation Probe), grab samples, and short cores. Part 2 was a cruise by the *Endeavor*, EN359 (August 12-September 10, 2001), during which UTIG and FAU investigators used a deep-towed chirp sonar supplied by FAU to image the upper ~30 m of the geologic section, at frequencies of 1-4 kHz/ 1-15 kHz and at profile separations ranging from 0.5 nmi to ~50 m (Figure 1). Secondary acquisition using a hull-mounted chirp sonar system was also conducted in Area 2. Part 3 was a second deep-towed chirp sonar cruise by *Endeavor*, EN370 (May 13-June 5, 2002), during which FAU investigators collected additional data in Area 2 at track-line spacings of 50-100 m.

RESULTS

Grab samples have been analyzed for grain size distribution at UTIG; these results have been correlated against ISSAP velocity measurements and backscatter intensity. Correlation analysis of sidescan backscatter and sedimentary properties has determined that: (1) compressional wave velocity is correlated with mean sand grain size and fine fraction; (2) backscatter intensity is correlated with the coarse fraction; and (3) compressional velocity and backscatter can be correlated only where coarse material is not a factor (Figure 2). Hence, coarse sediments (i.e., shell hash, gravel) tend to dominate backscatter where they are present in significant quantities (> ~5%). Unfortunately, this is true over much of the New Jersey outer shelf, so the backscatter map largely signifies coarse sediment content. In contrast, acoustic velocity is not significantly affected by coarse-grained material. Therefore, backscatter cannot be used as a direct proxy for velocity. Nevertheless, a strong relationship does exist between overall grain size and velocity (Figure 2), so a geologic understanding of the seafloor can provide a predictive tool for water/sediment interface velocity within the Geoclutter area.

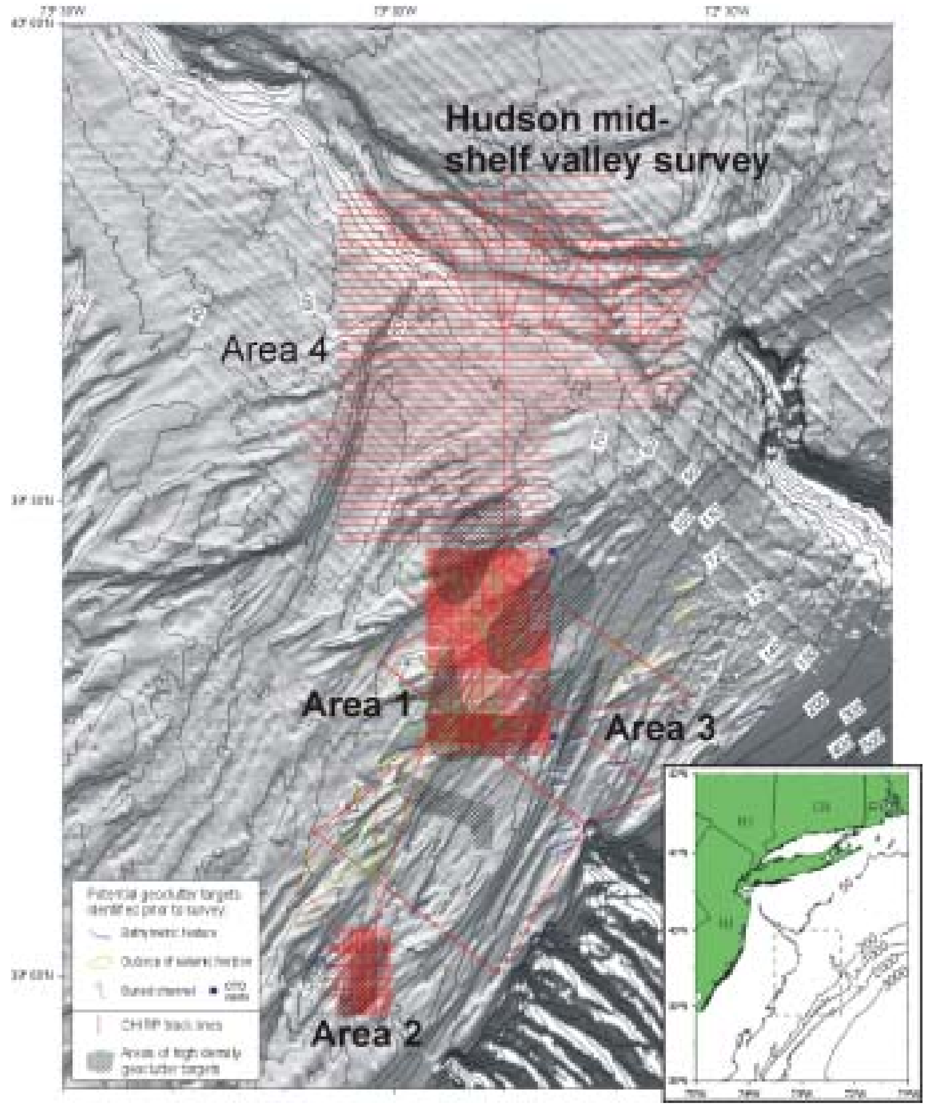

Figure 1. EN359 chirp sonar tracks (deep-towed/hull-mounted) on NOAA bathymetry. Inset shows Geoclutter study area in relation to the Mid-Atlantic Bight. Areas 1/2 were chosen based upon geoclutter target concentrations identified during Phase I. Area 1 was also intensively studied during STRATAFORM. Area 3 (cross-shelf) profiles tie chirp-sonar images to grab-sampling and seafloor velocity transects (cruise CH01-17). Area 4 (including zig-zag) profiles tie shallow subsurface drainage systems mapped in Area 1 to presumed proto-Hudson River drainage developed across the shelf during the last glacial lowstand ~20 ka. Track-line density varies between ~400 m and ~50 m.

Hardware/software capabilities put aboard *Endeavor* by UTIG for EN359 allowed chirp sonar data and precision navigation to be merged at sea. Subsequent mapping of important dendritic drainage patterns (Figure 3) and outcrops of important reflectors (i.e., "R") has since been refined. These maps confirm and amplify geophysical made during STRATAFORM. Some of these features correlate spatially with geoclutter targets identified during Phase I. More precise correlations between geophysical (i.e., chirp-sonar) characterizations of geologic features and geoclutter targets are underway. Phase II field activity continues with a September-October 2002 drilling/coring cruise aboard the Woods Hole Oceanographic Institution research vessel *Knorr*, cruise KN167, to address important STRATAFORM and Geoclutter targets in Area 1, 2 and 4 (Figures 1and 2), using the AHC-800 lake drilling system modified by DOSECC with "active heave compensation". In support of KN167, a POSMV inertial navigation system is being put aboard *Knorr* with funding from ONR to augment existing GPS/DGPS systems. *Knorr*'s DP system will also be re-calibrated, so that the best possible positioning in support of AHC-800 operations can be achieved.

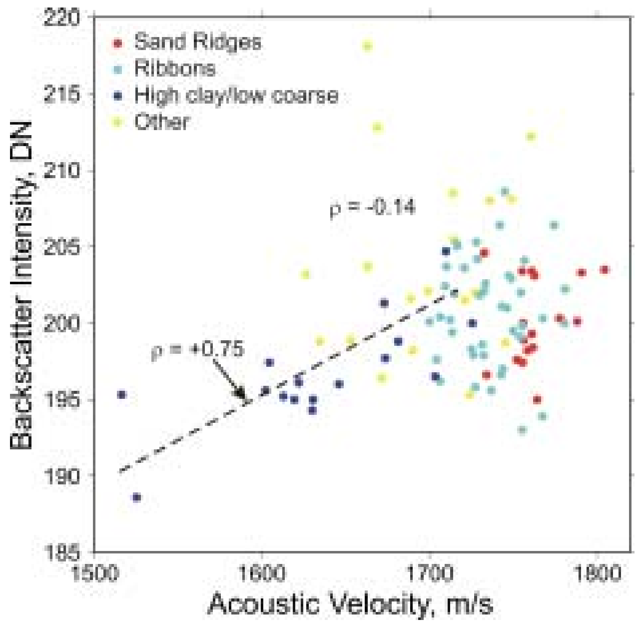

Figure 2. Comparison of ISSAP velocity measurements (courtesy L. Mayer, UNH) with co-located backscatter intensity. Each DN unit is equivalent to 0.5 db. Values shown are distinguished by geologic province. Sand ridges are a relict nearshore geomorphology: oblique-to-flow features >1 km wide composed of medium-to-coarse sands, winnowed of fine-grained sediment. Ribbons are low-relief, flow-parallel lineaments <1 km wide composed of high backscatter muddy/sandy shell hash interspersed with lower backscatter medium sand . The "high clay/low coarse" sediments, located mostly on the Hudson Apron, contain >10% fine and <5% coarse fractions. While different geological provinces exhibit different average velocities, only the "high clay/low coarse" sediments display a correlatable relationship between velocity and backscatter (indicated by correlation coefficients, ρ). We conclude that backscatter is primarily correlated with the coarse-grained fraction.

IMPACT/APPLICATIONS

Phase II chirp sonar interpretations (Figure 3) are available to Phase I investigators, so that prospective geoclutter targets in Areas 1 and 2 (Figure 1) can be tied to detailed geophysical characterizations of geologic features. Over the next ~3 years, Geoclutter will 1) understand, characterize, and predict lateral and vertical, naturally-occurring heterogeneities both at the seafloor and in the shallow sub-bottom of the mid- and outer continental shelf off New Jersey, and 2) identify, understand, characterize, and mitigate that geoclutter, specifically the heterogeneities that may produce discrete acoustic returns at low grazing angles, so that such false alarms, or detects, of tactical sonar systems can be put in a proper context.

TRANSITIONS

DURIP funding secured to equip the DOSECC GLAD800 lake-drilling system with active heave compensation has resulted in the AHC800 system. A test of that system was conducted offshore the U.S. east coast aboard the WHOI research vessel *Knorr* in November 2001. Cruise KN167 will conduct sampling operations off New Jersey in September-October 2002 to confirm the geologic identity of mapped Phase II geophysical targets.

RELATED PROJECTS

STRATAFORM/Geoclutter sampling in 2002 should proceed in tandem with additional Phase I acoustic reconnaissance, including perhaps future additional 2D and 3D chirp sonar imaging.

PUBLICATIONS

Austin, J. A., Jr., J. Goff, S. Gulick, C. Fulthorpe, S. Nordfjord, M. Wiederspahn, S Saustrup, S. Schock, J. Wulf, K. Gjerding, L. Mayer, and C. Sommerfield, 2001, Assessing the "GEO" in GEOCLUTTER: new chirp sonar, sampling, and compressional wave velocity results from the New Jersey shelf (abs). *Eos*, v. 82, no. 47, p. F655.

Nordfjord, S., S. Gulick, J. Austin, J. Goff, and C. Fulthorpe, in press, Late Quaternary incisions and related shallow subsurface stratigraphy on the New Jersey mid-outer shelf: Preliminary results from ultra-high resolution chirp sonar images - Part I (abs). *Eos*.

Fulthorpe, C., J. Goff, J. Austin, S. Gulick, and S. Nordfjord, in press, Late Quaternary incisions and related shallow subsurface stratigraphy on the New Jersey mid-outer shelf: Preliminary results from ultra-high resolution chirp sonar images - Part II (abs). *Eos*.

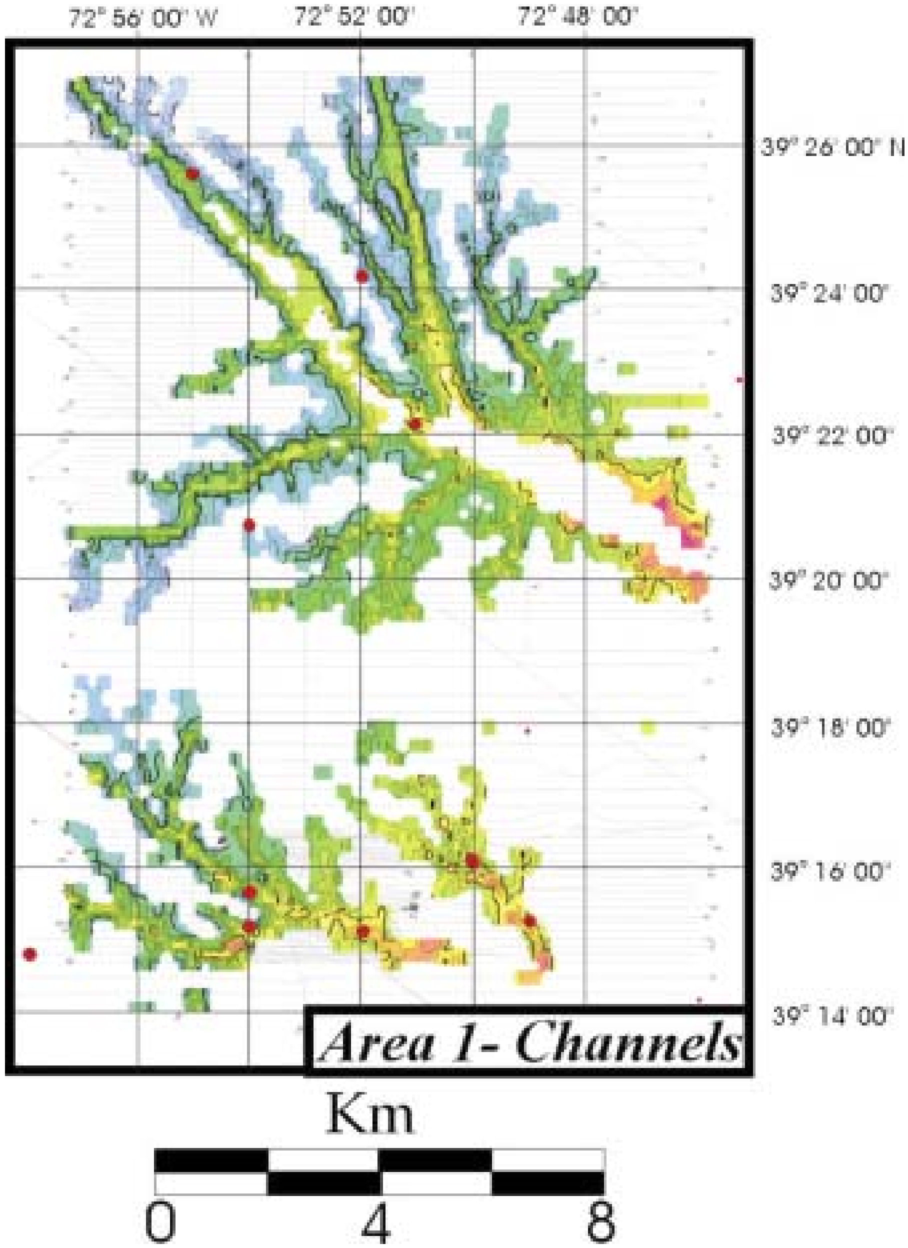

Figure 3. A dendritic network of fluvial(?) channels shallowly buried (<10 m) below the seafloor, interpreted from EN359 deep-towed chirp sonar profiles. Principal drainage axes are oriented NW-SE. Scales of incisions vary from widths of hundreds of meters and thicknesses of a few meters to widths of kilometers and thicknesses of tens of meters. Generally, trunk (main) channels have box–like cross-sections, with flat floors and high width/depth ratios. Smaller, tributary channels have v-shaped cross-sections with lower width/depth ratios. We believe variations in geometry within the drainage network are influenced by both magnitude of discharge and changing character of the flow regime with time.